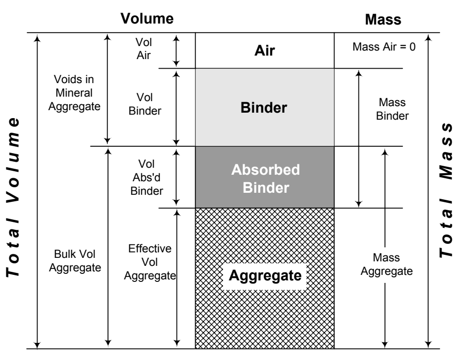
BASICS OF SUPERPAVE MIX DESIGNS

Introduction

02 Asphalt cement concrete (ACC) is a mixture of two primary ingredients: mineral aggregate and asphalt cement (AC) or asphalt binder as it is now termed. The binder holds the aggregate together in a moderately flexible rock-like mass. Hot mix asphalt (HMA) includes mixes that are produced at an elevated temperature. ACC and HMA are generally divided into three types of mixes, depending on the gradation of the aggregate: dense-graded, open-graded, and gap-graded.

Superpave HMA mixtures are a dense graded mix using high quality aggregates and asphalt binder used for the construction of surface courses on flexible pavements.



The binder is divided into two categories: absorbed (into the aggregate) and effective (which remains on the surface for binding aggregate particles together). Also, HMA contains air voids in addition to aggregate and binder.

Once the HMA mixture is mixed and compacted to optimum air void content (4%) it exhibits a certain level of stability that helps it withstand the combined action of environment and traffic loads. Several factors contribute to the level of stability offered by the HMA: the quality of aggregate and binder, and the gradation of the aggregate.

03 Five factors affect pavement performance:

1. Structural design
2. Mix design properties
3. Workmanship used to produce, place, and compact the mix
4. Loading factors
5. Environmental conditions.

This module presents information relating to item #2, Mix Design.

Mix Design

04 The objective of a mix design is to select the optimum asphalt binder content for a given aggregate source, binder source and optimum aggregate gradation. The FOP for AASHTO M 323 covers the Standard Specification for Superpave Volumetric Mix Designs.

The Superpave mix design and analysis system consists of three major components:

- Binder specification and selection
- Aggregate specification and evaluation
- Volumetric mix design and evaluation

The overall objective of the Superpave system is to specify the appropriate materials and mix design, and predict the performance of a given HMA pavement.

Binder

05 A binder specification is a process by which the designer can select and verify the appropriate grade of binder to be used on a specific project. To select a binder, it is important to understand how they behave:

How Asphalt Binders Behave

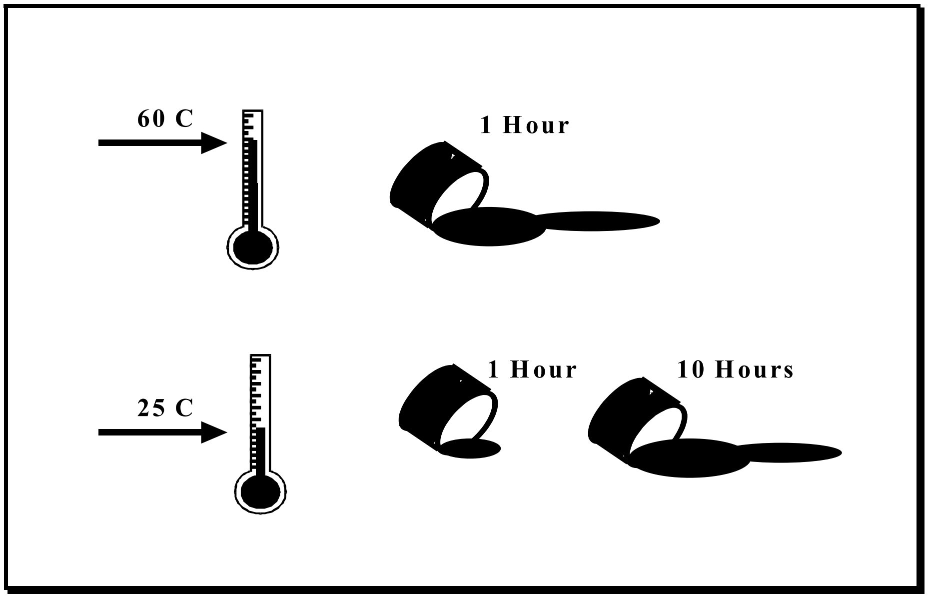
06 The behavior of asphalt binders depends on:

- Temperature
- Time (duration) of Loading
- Age

The first step in developing and understanding a binder grading system is to appreciate the behavior of the asphalt binder and the various factors that impact such behavior. Asphalt binders are viscoelastic materials whose behavior is dependent on temperature and time of loading. Because their chemical composition may change with time, their relative age in the road also impacts their engineering properties and, therefore, their behavior.

A unique property of a viscoelastic material is the superposition of temperature and time of loading. The impact of temperature and time of loading on asphalt binders are interchangeable. Testing the binder at elevated temperatures can simulate behavior of an asphalt binder, under a very slow loading rate.

Using such interrelationships, laboratory testing is used to simulate actual field conditions.



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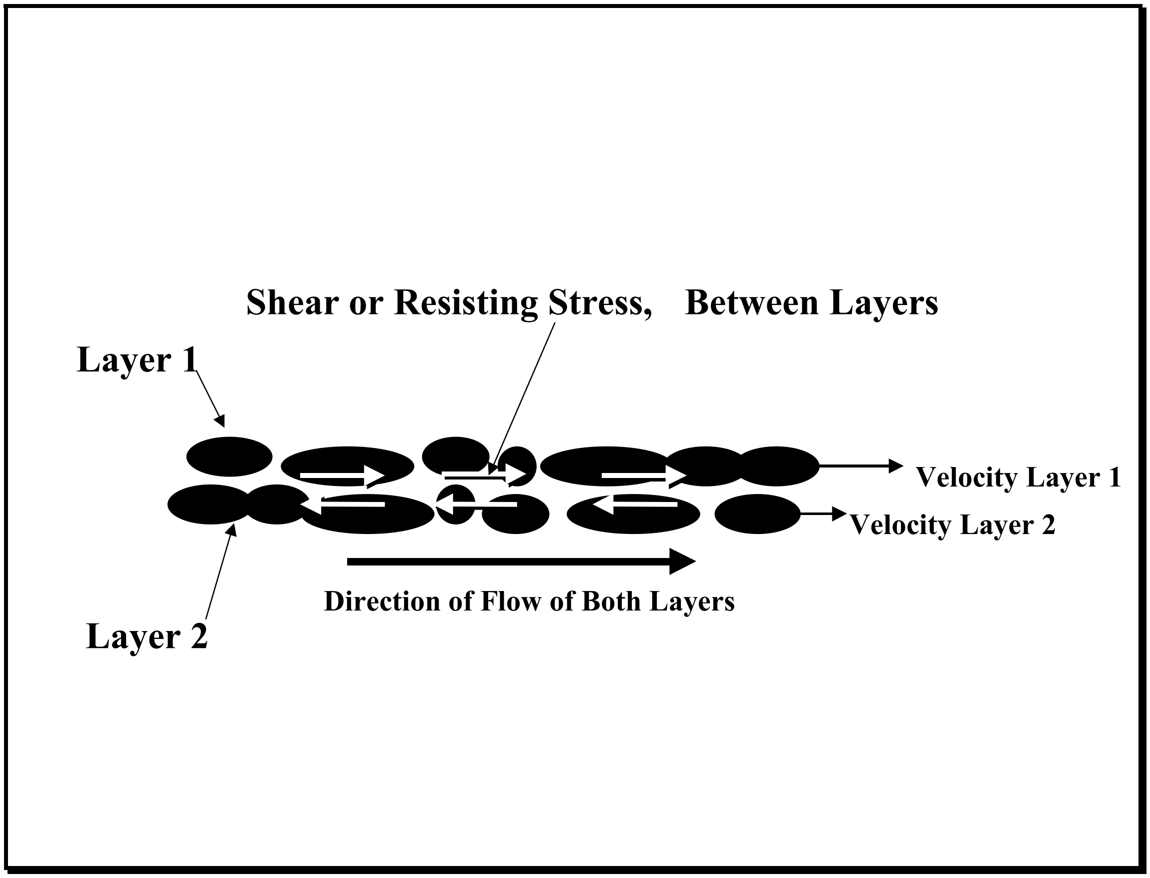
Temperature

07 The temperature that an asphalt binder is exposed to in the field depends on the location of the project. In high temperatures such as those found in desert climates and during summer the binder acts as a viscous liquid. At low temperatures such as those found in cold climates and during winter, the binder is an elastic solid which is more brittle. At intermediate temperatures the binder is viscoelastic, it has characteristics of both a viscous liquid and an elastic solid. Asphalt binders may be exposed to a range of extreme high temperatures to extreme low temperatures.



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09 At elevated temperatures, when asphalt binders behave as viscous liquids their resistance to shear deformations depend on the rate of shear stresses being applied. The resistance of asphalt binders to shear deformations controls the development of rutting in HMA mixtures.

Time of Loading

11 The time (duration) of loading that an asphalt binder encounters in the field depends on the actual use of the pavement facility. Pavements on parking lots, tollbooths and traffic lights are subjected to sustained loads. Pavements on highways and freeways are subjected to rapid loads.

The behavior of the asphalt binders changes from viscous liquids, as they are subjected to sustained loads, to elastic solids, as they are subjected to rapid loads.

At facilities where traffic speed is intermediate, the asphalt binder behaves as a viscoelastic material.

- Sustained loads = Viscous liquid
- Rapid loads = Elastic solid
- Intermediate loads = Viscoelastic

Aging Behavior

12 Aging of asphalt binders is a process by which the binders become more brittle with time.

During construction asphalt is subject to short-term aging due to hot mixing, and placing/compacting, which causes the volatiles to evaporate. In service asphalt is subject to long-term aging because asphalt reacts with oxygen, which results in oxidation or age hardening. Oxidation occurs more rapidly at elevated temperatures, a larger concern in hot, desert climates and hot summers.

In-place performance

13 The in-place life cycle of an HMA pavement depends on it’s ability to resist:

- Permanent deformation (rutting)
- Fatigue cracking
- Thermal cracking

These factors are taken into consideration in the mixture design selection of binder and aggregate structure. Because asphalt binders are significantly impacted by temperature, time of loading and aging HMA pavements are also impacted by the same factors.

Permanent Deformation

14 The aggregate gradation is the most significant contributor to a mixtures ability to resist permanent deformation (rutting) although binder properties are significant.

Fatigue Cracking

15 Fatigue cracking in HMA pavements occurs as a long-term response to in-service conditions. The resistance of HMA pavements to fatigue cracking is generated through a complex interrelationship among

binder, aggregate and pavement structure.

Thermal Cracking

16 Thermal cracking of HMA pavements is mainly controlled by the properties of the binder. Thermal cracking is caused by excessive tensile stresses due to shrinkage.

The asphalt binder carries these tensile stresses; as the binder ages, it becomes more brittle and its ability to resist tensile stresses diminishes.

17 Superpave PG Binder specification

The Superpave PG binder specification, as outlined in AASHTO M 320, measures the physical properties of asphalt binders that can be directly related to field performance by engineering principles.

Because of the viscoelastic nature of the binder, rheological testing must be performed to fully describe its engineering properties. (Rheology is the study of the deformation and flow of matter.)

The final outcome of the Superpave binder grading system is to assign a performance-based grade for the asphalt binder. This grade indicates the range of in-service temperatures of the binder to resist the various failure modes (rutting, fatigue and thermal cracking). The first number is the “high temperature grade”; the binder possesses adequate physical properties up to at least this temperature. The second number is the “low temperature grade”, and means the binder possesses adequate physical properties down to at least this temperature.

To identify the appropriate temperature range for the asphalt binder, its engineering properties must be evaluated at a temperature range that covers the expected temperatures during production, construction and service life.

High/Intermediate Temperature Properties

18 The high/intermediate temperature properties are measured by:

- Rotational Viscometer (RV)
- Dynamic Shear Rheometer (DSR)
  - Original (not aged)
  - Short-term aged = RTFO (Rolling Thin Film Oven)
  - Long-term aged = PAV (Pressure Aging Vessel)

Low Temperature Properties

19 The low temperature properties are measured by:

- Bending Beam Rheometer (BBR) at RTFO and PAV
- Direct Tension Tester (DTT) at RTFO and PAV
  - Short-term aged = RTFO (Rolling Thin Film Oven)
  - Long-term aged = PAV (Pressure Aging Vessel)

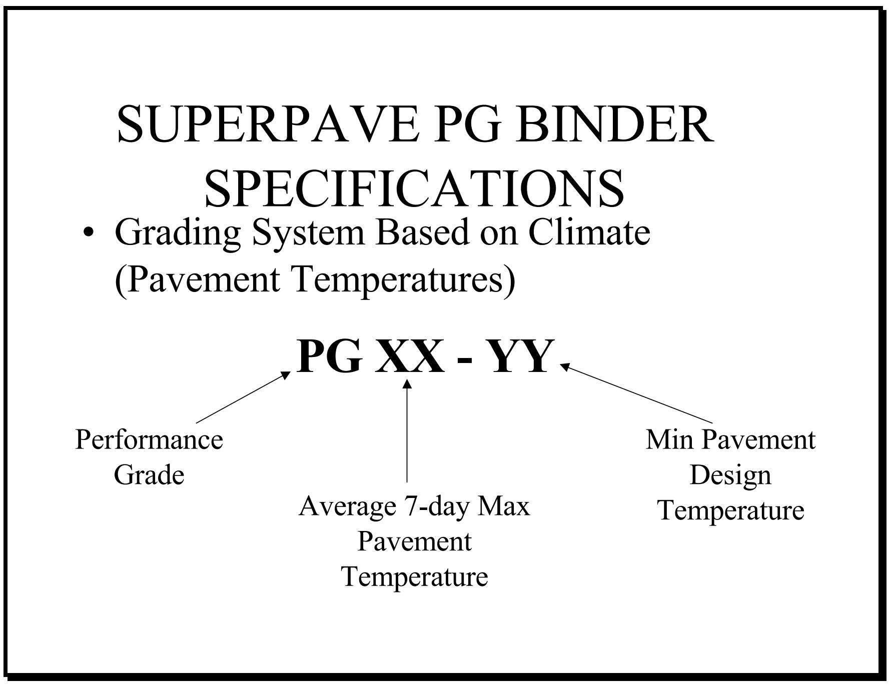
As the asphalt binder is subjected to different levels of temperatures at various stages of its service life, its engineering (rheological) properties significantly change. Therefore, the critical properties that control the resistance of the binder to the various failure modes have to be evaluated at the appropriate combinations of temperature and aging conditions of the binder.

Binder selection

20 The selection of the binder depends on the climatic condition of the project site:

- Low temperature
  - Lowest pavement temperature (not air temperature)
- High temperature
  - Average 7-day maximum pavement temperature (not air temperature)

The selection of the asphalt binder also makes some adjustments for the anticipated traffic speed.



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Basics of Superpave Aggregate Specifications

The aggregate specifications include:

- Coarse aggregate angularity (AASHTO TP 61)
- Fine aggregate angularity (AASHTO T 304)
- Flat and elongated particles (ASTM D4791)
- Clay content (AASHTO T 176)

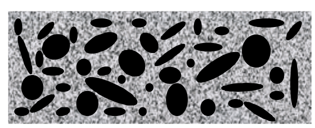
Because aggregates make up 95 percent of the HMA mix, their properties are critical to the performance of the mix. The Superpave mix design system specifies critical properties for the fine and coarse portions of the aggregates. Fine aggregates are defined as passing the #4 (4.75mm) sieve. Coarse aggregates are defined as retained on the #4 (4.75mm) sieve.

The gradation of the aggregates controls the long-term performance of the HMA mix. The concept of the gradation specification is that a dense graded mix, which does not experience tenderness during the construction process, should provide good performance.

A large portion of the Superpave aggregate specification deals with the physical shape of the aggregate because it significantly impacts the interlocking and adhesion properties of the aggregates.

Contrasting Stone

Cubical Aggregate



Rounded Aggregate

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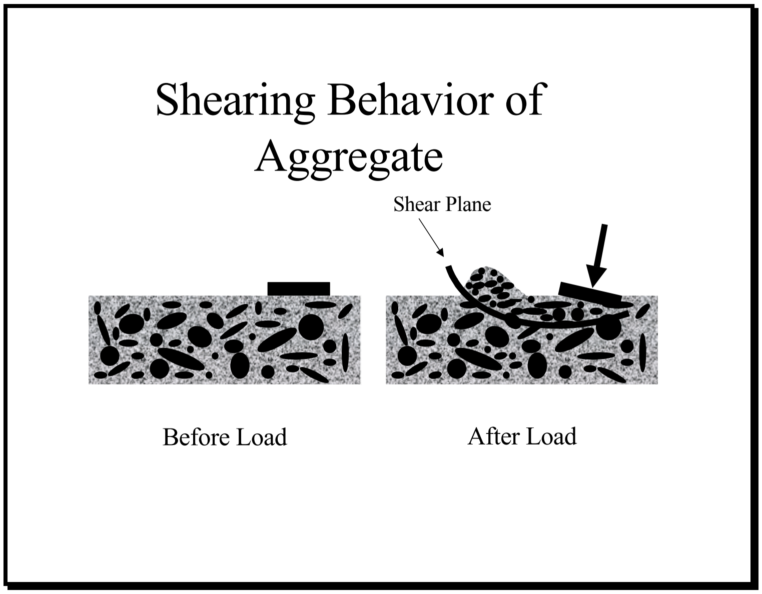

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The rutting resistance of the HMA mixture is highly dependent on the interlocking of the aggregate particles. Rounded and smooth aggregates slip relative to each other when subjected to loads. Therefore, the resistance of HMA mixtures to shear deformations is increased when large percentages of cubical and rough aggregates are used.

The design aggregate structure approach ensures that the aggregate will develop a strong, stone skeleton to enhance resistance to rutting while allowing for sufficient void spaces to enhance mixture durability.

25 **Gradation Controls**

- Nominal Maximum Size
- 0.45 power chart
- Control points

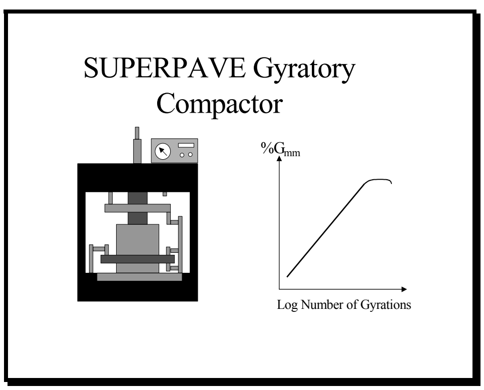
26 **Aggregate Source Properties**

The Superpave aggregate specifications also recognize properties of that are controlled by the aggregate source:

- L. A Abrasion (AASHTO T 96)
- Soundness (AASHTO T 104)
- Clay lumps and friable particles (AASHTO T 112)

These aggregate specifications include properties that are considered to be critical to the overall quality of the aggregate particle. It is up to the highway agency to set the limits that have worked well under local conditions.

27 **Mix Design Overview**



28 The Superpave system includes:

- **Volumetric Mix Design**
- Performance based tests
- Performance prediction

This module is concerned with the Volumetric Mix Design.

29 The **Volumetric Mix Design** includes:

- Materials Selection (Aggregate & Binder)
- Gradation Selection (Trial Series)
- Optimum Binder Content Selection

Definition of Terms

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- G_{mm} =theoretical maximum specific gravity
- G_{mb} = measured bulk specific gravity
- G_{sb} = bulk specific gravity of aggregate
- G_{sa}= apparent specific gravity of aggregate
- G_{se}= effective specific gravity of aggregate
- G_{b}= specific gravity of the binder
- V_{a} = air voids

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- VMA= voids in mineral aggregate
- VFA=voids filled with binder
- V_{ba} = absorbed binder volume
- V_{be}= effective binder volume
- P_{b} = percent binder content
- P_{ba} = percent absorbed binder
- P_{be} = percent effective binder content

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- P_{s} = percent of aggregate
- $P_{.075}/P_{be}$= dust to effective binder ratio
- RAP=Reclaimed Asphalt Pavement
- Nominal Maximum Aggregate Size=
  One sieve size larger than the first sieve to cumulatively retain more than 10%
- Maximum Aggregate Size=
  One sieve size larger than the nominal

33
  maximum aggregate size
- Design ESALs=
  Design equivalent 18,000 lbs (80kN) single axle load
  Design ESALs are the anticipated project traffic level expected over a 20-year period. For pavements designed for more or less than 20 years standard load equivalent factors are used. ESALs should be calculated for a 20-year design life.

34

Prerequisite Tests

- AASHTO T 2 Sampling of Aggregates
- AASHTO T 248 Reducing Samples of Aggregate to Testing
- AASHTO T 11 Materials Finer than 75μm (No. 200) Sieve in Mineral Aggregate by Washing
- AASHTO T 27 Sieve Analysis of Fine and Coarse Aggregates
- AASHTO T 85 and T 84 Specific Gravity of Fine and Coarse Aggregates

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Optimum Aggregate Gradation Selection (General)

1. Establish three trial aggregate gradations that meet all aggregate requirements.
2. Determine initial binder content for each trial aggregate gradation.
3. Compact two samples for each trial aggregate gradation at the initial binder content.
4. Measure volumetric properties of the compacted samples.
5. Estimate volumetric properties at V_a= 4.0%.
6. Select the aggregate gradation that best satisfies the design criteria.

Select Optimum Binder Content
37 (General)

1. Prepare and compact replicate samples of the design gradation at four levels of binder content. (Est. design, 0.5% below, 0.5% above and 1.0% above)
2. Measure volumetric properties of the compacted samples.
3. Determine the optimum asphalt binder content.

38

4. Check the volumetric properties at the optimum binder content against the design criteria.
5. Check design criteria at N_{max} (replicate specimens).
6. Check moisture sensitivity of the mixtures at the recommended P_b (AASHTO T 283).